An Analysis of Health Impacts Associated with Pollutant Response to Changes in Emissions In Different Regions of Central California

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Introduction

Exposure to ambient air pollutants such as ozone and particulate matter (PM) has been shown to have considerable human health impacts. Currently, major air basins of central California such as the San Francisco Bay Area (SFBA), Sacramento area, and the San Joaquin Valley (SJV) are all designated as in nonattainment of the US EPA 8-hour ozone and 24-hour $PM_{2.5}$ standards, despite California's comprehensive emission control programs for the last fifty years.

Although these programs were very effective, decreasing anthropogenic emissions 40 to 50 percent in the region from 1990 to 2010 alone, the ambient response of pollutants was mixed and varied among these three interconnected regions.

The purpose of this work was to investigate differences in each region's public health response to changes in emissions using the US EPA's BenMAP program (US EPA, 2010). Emphasis was placed on PM, and results are given in terms of rates for mortality and monetary value for morbidity.

Air Quality Modeling

Inputs to BenMAP were prepared using the CMAQ model.

- Four-km horizontal grid resolution
- Emissions inventory development (SMOKE)
- Meteorological modeling (MM5)
- Photochemical $PM_{2.5}$ modeling (CMAQ)
- Model performance evaluation for meteorological and air quality models
- Annual average $PM_{2.5}$ levels were estimated as the average of quarterly averages over four seasons. $PM_{2.5}$ levels were explicitly simulated for the winter season, which experience the highest PM levels. As a preliminary estimate, the winter $PM_{2.5}$ spatial distribution was scaled to represent other seasons.

Health Impacts Modeling

BenMAP

- Overlays population data onto changes in pollutant levels to estimate health impacts
- Estimates monetary value of health effects for both morbidity and mortality. Results reported per year.
- Includes the amount people are willing to pay to avoid adverse health effects including premature death

BenMAP Inputs

- Simulated PM2.5 concentrations (4-km horizontal resolution)
- 2000 US Census

Health Benefit Scenarios

Scenario 1: Reducing direct $PM_{2.5}$ emissions

- Simulated 2006 PM2.5 levels (base case)
- 40% across-the-board reductions in anthropogenic direct $PM_{2.5}$ emissions (control case)

Scenario 2: Reducing $PM_{2.5}$ precursor emissions

- Simulated 2006 PM2.5 levels (base case)
- 40% across-the-board reductions in anthropogenic $PM_{2.5}$ precursor emissions (control case)
  - Affected precursors include NO_x, NH_3, SO_x and VOC

RESULTS

Scenario 1

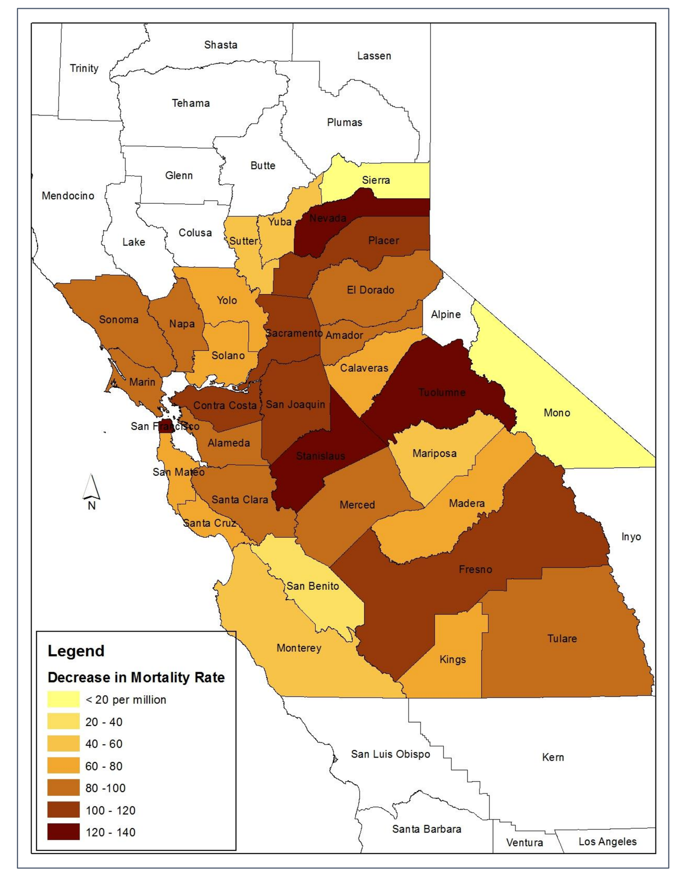

Figure 1. Impacts of a 40% reduction in direct PM emissions upon annual mortality rates.

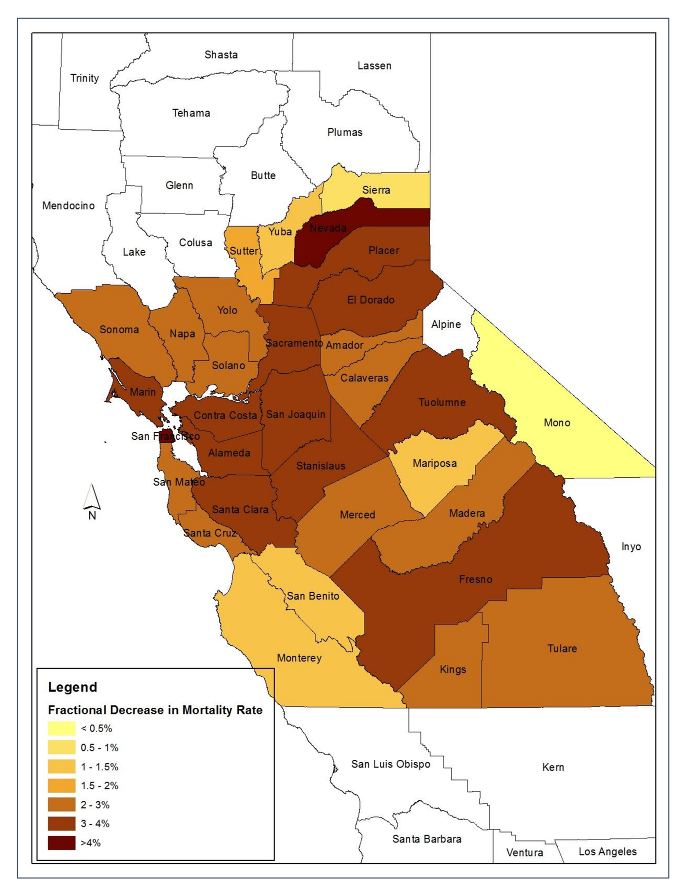

Figure 2. Impacts of a 40% reduction in direct PM emissions upon mortality rates, given as fractions of total non-accident mortality.

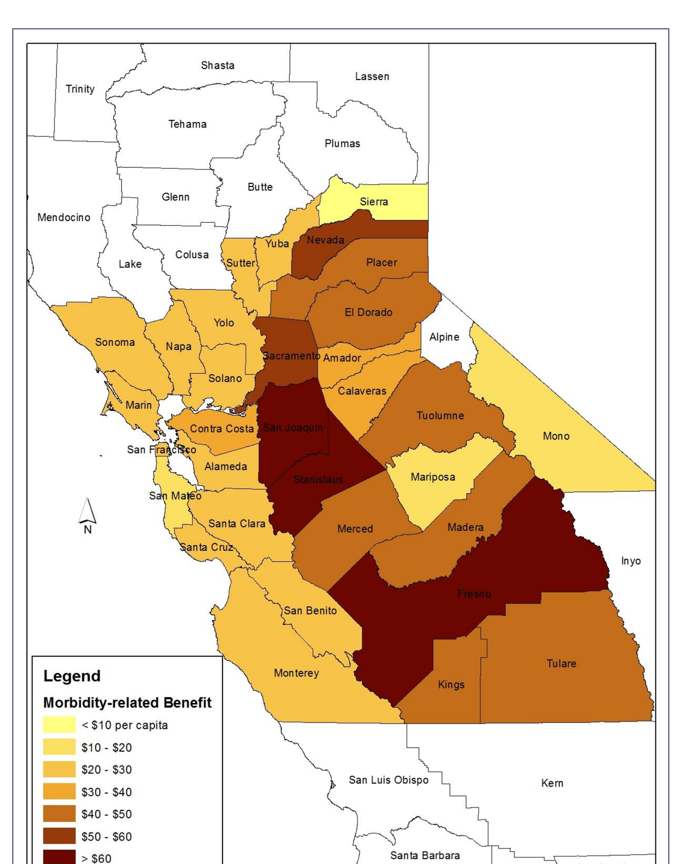

Figure 3. Impacts of a 40% reduction in direct PM emissions upon morbidity-related valuation. (dollars per capita per year)

Scenario 2

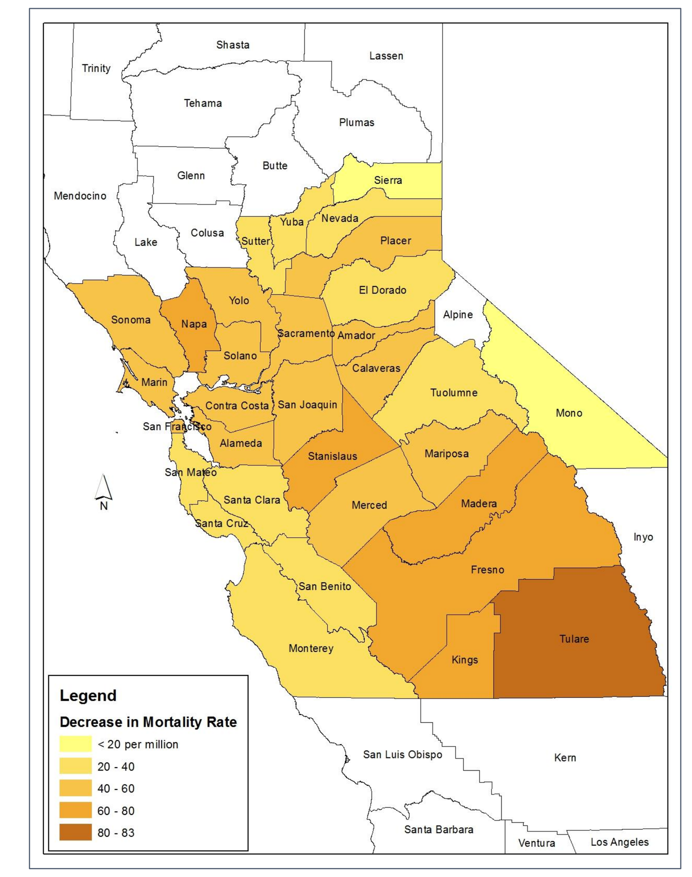

Figure 4. Impacts of a 40% reduction in PM precursor emissions upon annual mortality rates.

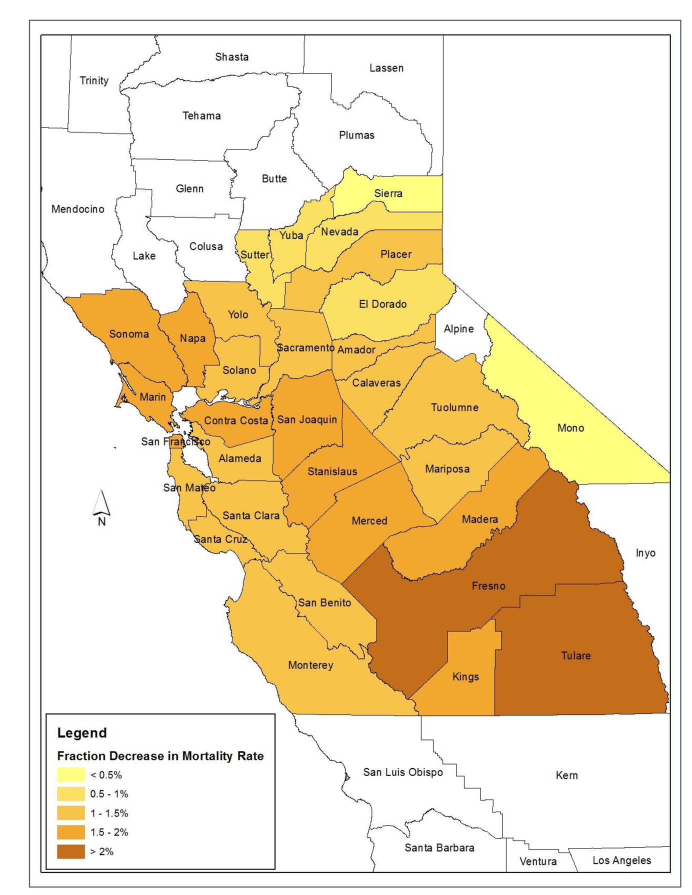

Figure 5. Impacts of a 40% reduction in PM precursor emissions upon mortality rates, given as fractions of total non-accident mortality.

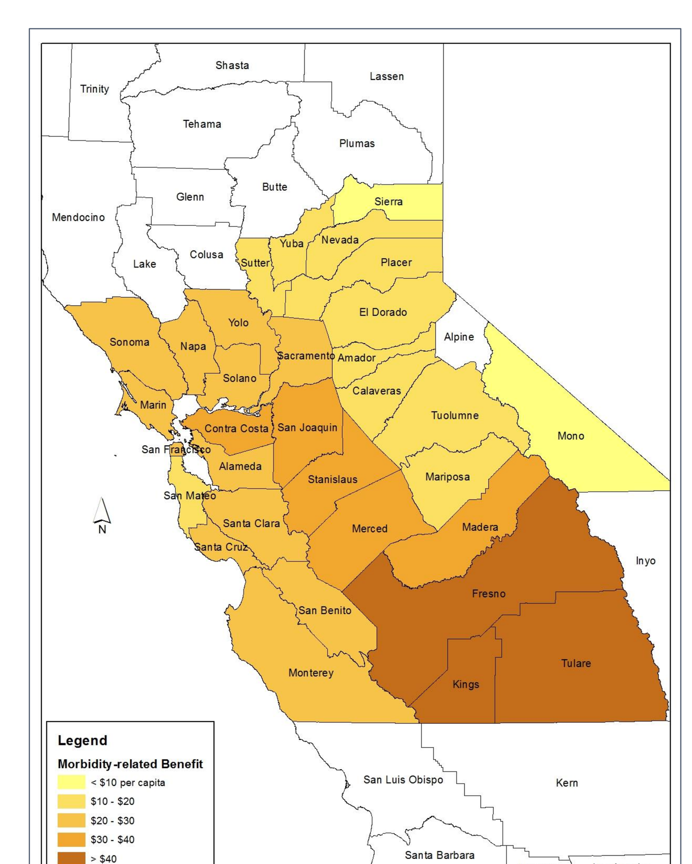

Figure 6. Impacts of a 40% reduction in PM precursor emissions upon morbidity-related valuation. (dollars per capita per year)

Discussion

Figures 1-3 show health impacts for direct PM emission reductions, and Figures 4-6 show results for secondary PM reductions. Figures in the top two rows are related to mortality whereas the bottom row shows morbidity impacts in terms of monetary valuation. (Valuation, rather than incidence, is reported for morbidity because this category contains a variety of health endpoints with very different monetary values. For instance, a heart attack costs much more than a restricted activity day. Looking at incidence may mask this important fact so valuation is a better metric to use.)

Mortality results in Figures 1 and 4 were normalized by population to allow comparison across counties. The impacts of direct PM emission reductions were larger than for precursor emission reductions. San Francisco and Stanislaus Counties expected reductions in mortality rates as high as 120-140 per million from direct PM reductions. Tulare County, with the largest impact from PM precursor reductions, showed only half of this benefit. However, for that county, precursor effects were about equivalent to direct PM impacts.

Because BenMAP uses background incidence rates to estimate changes in incidence, mortality rates in Figures 1 and 4 were normalized by the overall non-accident mortality rate for each county, available from the Department of Health and Human Services (2008), to isolate the impact due to changes in air quality. This is shown in Figures 2 and 5, respectively.

- With regards to direct PM emissions' impacts, densely-populated San Francisco county in the SFBA showed the highest percentage reduction in mortality. Furthermore, the region comprised of the East Bay counties of the SFBA, Sacramento Valley, and northern SJV all shared similar benefits. This suggests that the air quality changes for these counties were interrelated.
- With regards to PM precursors, the southern end of SJV showed the largest impacts. In the SFBA, the northern counties were expected to reap the largest reduction in mortality rates.

In the Central Valley, morbidity impacts for both scenarios generally followed the spatial patterns found for mortality. The Bay Area showed relatively low morbidity-related impacts, on a per capita basis.

Summary

In general, the public health benefits of direct PM emission reductions are larger than those resulting from comparable reductions in PM precursor emissions for all three regions.

The SJV would see the greatest benefits from a 40% reduction in PM precursor emissions, particularly in the southern end of the valley.

The health impacts from direct PM reductions for the eastern SFBA, Sacramento valley and northern SJV are related.

References

US EPA (2010), BenMAP – Environmental Benefits Mapping and Analysis Program: User's Manual, Prepared by Abt Associates.

US Dept. of Health & Human Services (2008), Community Health Status Indicators Report, Available online at http://communityhealth.hhs.gov/chsi2008/homepage.aspx?j=1.